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Research Methods in Biomechanics

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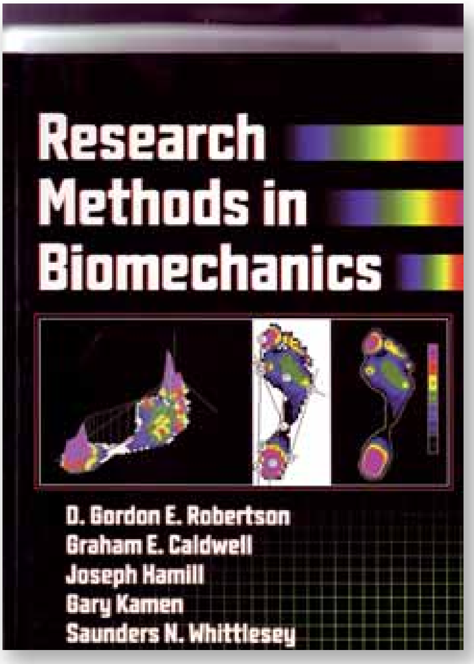

Like every other scientific discipline, biomechanics uses a specific set of knowledge, insturments and analytical techniques, which must be mastered before one can conduct research and contribute new knowledge. *Research Methods in Biomechanics* is a comprehensive resource on the tools of this trade aimed at scientists. Its structure is also an overview of the work of the biomechanist, providing some additional interest for sports researchers and sports students.

However, it must be emphasized from the outset that this is not an easy read. The authors are all well known in their field and are represented in the relevant journals or have produced other books about biomechanics. They assume a certain grasp of geometry, trigonometry and algebra, including elementary vector algebra, as well as a familiarity with basic mechanics and Newton's laws, although many examples of their application are provided. It is also necessary for the reader to have a good working knowledge of human anatomy, as awareness of the constraints imposed by the body's structure is essential for understanding the mechanics involved.

Problems related to locomotion and postural control are a major area of focus for many biomechanists. The linear and angular motions that can be seen are described by kinematic variables measured using an imaging system, such as a film or video camera, or instruments attached to joints to register displacement. Methods for acquiring data and computing "Planar Kinematics" are covered in Chapter 1 ("Description of Position; Degrees of Freedom; Kinematic Data Collection; Linear Kinematics; Angular Kinematics"). However, some motions may be too complex to describe using simple planar or two-dimensional (2-D) coordinates. Thus, we learn in Chapter 2 about "Three-Dimensional Kinematics" ("Scalars, Vectors, and Matrices; Collection of Three-Dimensional Data; Coordinate Systems; Marker Systems; Determination of the Local Coordinate System; Transformations Between Reference Systems; Joint Angles; Segment Angles").

Analysing motion patterns requires computers to capture obtained images and from them calculate the trajectories of reflective markers placed over a subject's joints. These data are then processed to derive kinematic measures, such as joint range of motion, the velocity and acceleration of each segment, and the path of the centre of gravity (CG). The methods for determining the "Body Segment Parameters" are detailed in Chapter 3 ("Methods for Measuring and Estimating Body Segment Parameters; Two-Dimensional (Planar) Computational Methods; Three-Dimensional (Spatial) Computational Methods").

To go beyond kinematic description and understand why motions occur as they do, the kinetics, or underlying linear forces and rotational torques, that dictate the kinematic motion must be examined. "Forces and Their Measurement" are dealt with in Chapter 4 ("Force; Newton's Laws; Free-Body Diagrams; Types of Forces; Moment of Force, or Torque; Linear Impulse and Momentum; Angular Impulse and Momentum; Measurement of Force"). The description of methods of recording and analysing given here includes how to use force platforms to measure ground reaction forces (GRFs).

After measuring GRFs and computing 2-D or 3-D motion patterns, inverse dynamics analysis is used to calculate for each joint the smallest possible force that is necessary to complete a given action. Inverse dynamics analysis uses Newton's second and third laws to determine what forces and moments of forces exist at each point. The theory and methods for performing "Two-Dimensional Inverse Dynamics" analyses for planar motions are introduced in Chapter 5 ("Two-Dimensional Inverse Dynamics; Planar Motion Analysis; Numerical Formulation; General Plane Motion; Method of Sections; Human Joint Kinetics; Applications") and Chapter 7 develops the techniques for "Three-Dimensional Kinetics" analyses ("Laboratory Setup; Data Required for Three-Dimensional Analysis; Sources of Error in Three-Dimensional Calculations; Three-Dimensional Kinetics Calculations; Presentation of the Data").

The biomechanist can also compute the mechanical cost of the work done and the mechanical power required at each joint. How "Energy, Work, and Power" are derived from kinematic and kinetic measurements is explored in Chapter 6 ("Energy, Work, and the Laws of Thermodynamics; Conservation of Mechanical Energy; Ergometry: Direct Methods; Ergometry: Indirect Methods; Mechanical Efficiency").

The precise forces produced by the muscles and transmitted through the tendons, ligaments, and bones can be directly measured only with indwelling force sensors or estimated by modeling the musculoskeletal system. Alternatively, the activation patterns of the muscles can be measured to better quantify the role of the muscles during performance of the tasks. Muscle activation can be studied using electromyography (EMG). Techniques for recording and interpreting EMG signals are covered in Chapter 8, "Electromyographic Kinesiology" ("Physiology of the Electromyographic Signal; Recording and Acquiring the Electromyographic Signal; Analyzing and Interpreting the Electromyographic Signal; Applications of Electromyographic Techniques").

Although kinematic, kinetic, and EMG analyses are indispensable for studying actual movements, the question that remains is whether certain movements, e. g. stair climbing, can be performed in a more efficient or effective manner. What is, for example, the optimal way for a person to ascend stairs? Forward dynamics models address such questions by simulating a movement given a set of internally applied forces and torques. Once the model is customized for a specific individual, optimal control techniques are used to find the "best" set of forces and torques needed to accomplish the task. When results from optimisation models are compared with the actual movement produced by a human stair climber, ways in which he or she can improve his or her performance may come to light. Muscle models that mimic the force-generating capabilities of actual muscles can be used to provide values for the internal forces in these forward dynamic models. Use of these models is essential to biomechanics research because the technology for measuring individual muscle forces is highly invasive and unsuitable for use in most research situations. The modeling of muscles to better understand their function is reported on in Chapter 9, "Muscle Modeling" ("The Hill Muscle Model; Musculoskeletal Models"), while the topics of "Computer Simulation of Human Movement" and forward dynamics are discussed in Chapter 10 ("Overview: Modeling As a Process; Why Simulate Human Movement?; General Procedure for Simulations; Free-Body Diagrams; Differential Equations; Model Derivation: Lagrange's Equation of Motion; Numerical Solution Techniques; Control Theory; Limitations of Computer Models").

Many different types of data are required to perform these analyses. For example, quantifying the motions of reflective markers placed over joint centres requires that the video data be digitised using high-speed computers to obtain the positions of the body segments during the activities under study. To determine velocities and accelerations, mathematical time derivatives are computed using algorithms that require special smoothing techniques to be applied. The researcher must know which technique is appropriate for use and then evaluate whether the technique was successful. Although these topics are discussed in detail throughout the text, Chapter 11, "Signal Processing," in particular, describes various data-smoothing and -processing techniques that result in reliable, noise-free data ("Characteristics of a Signal; Fourier Transform; Wavelet Transform; Sampling Theorem; Ensuring Circular Continuity; Smoothing Data").

Each of the chapters described in this overview is concluded with a summary and suggested readings. Apart from the reference materials, *Research Methods in Biomechanics contains* extensive tables and figures as well as exercises, allowing the reader to test his or her skills and enhance his or her understanding of the material.

The Appendix consists of nine parts: A – International System of Units; B – Selected Factors for Converting Between Units of Measure; C – Basic Electronics; D – Vector Operations; E – Matrix Operations; F – Numerical Integration of Double Pendulum Equations; G – Derivation of Double Pendulum Equations; H – Discrete Fourier Transform Subroutine; I – Shannon's Reconstruction Subroutine.

All in all, this book is a comprehensive contribution to the field of biomechanics and provides a firm foundation in the biomechanical methods and tools necessary for quantifying human movements. It is a must-have for biomechanics professionals and researchers, motor behaviorists and ergonomists. It is also valuable reading for undergraduate and graduate students enrolled in biomechanics methods courses.

Reviewed by Jürgen Schiffer

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